AD-A049 838 NAVY ELECTRONICS LAB SAN DIEGO CALIF F/G 17/1
A MULTICOLOR STORAGE DISPLAY.(U)
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UNCLASSIFIED NEL-TM-411 NL

1 of 1
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3-78
DDC

MOST Project-3

S-F001 03 02

SUBTASK

PROBLEM NEL E1-3

(14) NEL-TM-411

(9) technical memorandum no.

(11) 8 June 1960
date

(12) 21p.

(1) B. C.

(6) A MULTICOLOR STORAGE DISPLAY.
title

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author

2633
code

(16) FØØ1Ø3

(17) SFØØ1Ø3Ø2

(21) ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

U. S. Navy Electronics Laboratory, San Diego 52, California

A MULTICOLOR STORAGE DISPLAY

by

R. K. Betsworth

INTRODUCTION

This memorandum describes the preliminary work conducted to determine whether the color parameter in a multicolor storage tube would enhance the detection of submarine targets in a noise or reverberation background and, also, to evaluate the performance of the Hughes electronic color storage display device. The work was done under NEL Problem E1-3. This memorandum should not be construed as a report as its only function is to present, for engineering purposes, information concerning a portion of the work being done on sonar display devices.

The display device used in the experiment was a ten-inch color storage tube, figure 1, developed by Hughes Aircraft Company under Air Force Contract AF(616)-2177. The tube, serial 10-11, was on loan to Code 2633 from Wright Air Development Center and was received at NEL on 13 January 1959.

The tube is a three-gun, color storage tube in which three electron beams are used; one for each primary color (i.e., red, blue, green). The tube dimensions and other general specifications are given in Table I. Operating data for Color Tube 10-11 is given in Table II.

DATA DISPLAY

The sonar data displayed was in digital form and had been computer processed. The computer processing and data simulation was performed using the input/output logical circuitry and magnetic storage drum of a Remington Rand Deltic having a memory of 2000 words, word length

of 18 bits, and read-out time of 5 milliseconds per word. The parameters represented by the digital word consisted of range, bearing, range rate, and amplitude. The word assembly showing the number of bits associated with each parameter is shown in figure 3.

The digital information was read out of the Deltic and displayed in the following manner (figure 4). The vertical and horizontal positioning of the electron beam from an initial reference point in the lower left hand corner of the tube face represented range and bearing, respectively. This was performed using digital-to-analog converters in the vertical and horizontal driving circuitry (figure 5). Range rate was represented by color, where red indicated up-doppler, blue indicated down-doppler, and green indicated zero doppler. As soon as the electron beam was positioned to indicate range and bearing, a particular color gun representing range rate was pulsed on for a time interval proportional to the amplitude of the word. During the time the color gun was pulsed on, the beam was swept across the screen writing a line to represent the amplitude of the word. The line written had eight (2^3) different possible lengths, with a maximum length of 0.75 inches. The gating of the color guns and the digital-to-time interval conversion was performed using "T-Pac" logical elements purchased from the Computer Control Company, Inc., Framingham, Massachusetts.

To limit the density of the reverberation or noise background words, an amplitude threshold was provided, allowing only data that exceeded an arbitrary amplitude to be displayed. For data simulation techniques, see Appendix II. (Noise and reverberation words were limited to amplitude levels of 3 and 4 on a scale of 8. Target words were represented by amplitude levels of 5 or greater).

Ten seconds were required to read out all of the words from the Deltic and display the information. The persistence of the color storage tube was approximately 2 minutes, after which deterioration of the stored information was appreciable.

THE EXPERIMENT

The objective of the experiment was to determine how well a human operator was able to pick targets from a background of noise or reverberation displayed on each of two display devices. Photographic slides of the two displays were projected in two sections. The first section consisted of black and white slides of the Hughes Tonoscope display. For each color slide shown, an associated black and white slide containing the same information was shown so that a direct comparison between the two displays could be made. Samples of some of the photographic slides used in the experiment are shown in figure 6.

Seven human operators, familiar with the detection task and philosophy of the test, participated in the experiment. The slides, Table II, shown to them contained a background of simulated random noise (750 words) or reverberation (1000 words) and a few targets. Because of the target-like patterns generated by the noise or reverberation background (particularly true on the Tonoscope display where there was no color choice), it became apparent that the false alarm counts would be excessive if some criterion were not placed on the number of targets to expect on any one slide. For this reason, each operator was told before the test began that the maximum number of targets on any one slide was three and a search time of 20 seconds would be allowed for each slide.

During the test, the operator chose the targets and indicated their location on the screen. The experimenter, knowing the exact

location of the targets, recorded the number of targets chosen, the number of targets missed, and the number of false alarms.

RESULTS OF THE EXPERIMENT

The averages of the experimental results are recorded in Table III. The individual operator results varied over the range of 0 to 3 false alarms with a maximum of one target missed for any one black and white slide of the Tonoscope display and from 0 to 1 false alarm and 0 targets missed for any one color slide of the 3-Color Tube display. From this table, it is seen that the false alarm count associated with the Tonoscope display was considerably greater than that of the 3-Color Tube display. The reason for this was the greater resemblance between targets and the patterns generated by the noise or reverberation background. In the color display, noise or reverberation words written adjacent to each other could often be discriminated from a target by means of the color associated with the words. That is, noise words on the 3-Color Tube display might be represented by red, blue, or green noise levels written adjacent to each other, but on the Tonoscope display they would appear as a continuous white line of sufficient length to indicate a target. For the same reason, the number of targets missed was greater on the Tonoscope display where adjacent noise or reverberation words would appear as a level of greater amplitude than that of a low level target. It is also evident that the false alarm count associated with the 3-Color Tube display would be less with the noise limited background than with the reverberation background where there are a large percentage of zero doppler reverberation words, although the results of the limited tests made do not indicate this.

It was desired to obtain from the color display slides a comparison of the degree of detectibility of targets when presented in a noise limited background and when presented in a reverberation limited background where 90% of the background indicated zero doppler words. However, from the results obtained, the degree of detectibility of targets in the two different backgrounds was inconclusive.

A comparison was made between an A-Scan presentation and a B-Scan presentation. The results of the experiment indicate that an A-Scan presentation, where data from all bearings were superimposed, might be the most desirable display from the standpoint of initial target detection. There were no false alarms or missed targets indicated in the results of the A-Scan presentation on either of the two display devices.

COLOR STORAGE TUBE PERFORMANCE

The resolution of the tube was measured by the shrinking raster method. With optimum gun adjustments, the resolution of the tube, storing the colors in three independent tests, was determined to be 25 lines per inch using the green gun, 20 lines per inch using red, and 20 lines per inch using blue.

The variations in screen brightness for the three colors was measured using a Spectra Brightness Spot Meter. The results of the test are depicted in figure 7. The surface viewed by the Spot Meter was enclosed in a circle of 1/2 inch diameter. The area viewed during the test was a solid color pattern, 2 inches wide by 5 inches in height, stored on the left hand portion of the screen. With optimum adjustments and equal dynamic biasing voltages for each gun, the maximum intensity measured, without the guns over-writing, varied from 0.23 foot lamberts

for the green color, 0.19 foot lamberts for blue, to 0.016 foot lamberts for red. Because of the low viewing intensity of the storage tube, the display had to be viewed in a darkened room.

The usable retention time of the display was approximately 2 minutes, after which time, the stored pattern had deteriorated appreciably (Photograph D of figure 6).

With what was considered to be optimum adjustment of the tube controls, the pattern stored on the lower portion of the screen contained color impurities, apparently inherent in the tube. Also, in this area, the intensity was very low and written information was difficult to distinguish.

A five level halftone range is claimed for this tube. In an attempt to utilize the halftone range to provide integration, the same word was rewritten several times at various writing intensities. However, no adjustment was obtained which produced any significant integration effect.

CONCLUSIONS

1. In a B-Scan presentation, the color parameter in a color display device enhances the detection of a target in either a noise or a reverberation background when the color is used to display doppler.
2. In a B-Scan presentation, the false alarm count is reduced when the displayed information is presented in color when the color is used to display doppler.
3. The A-Scan presentation used is more desirable for initial target detection than a B-Scan, as deduced from the limited tests made.

4. Improvements in the level and uniformity of the surface brightness would make the 3-Color Storage Tube a much more desirable display device.

5. Improvements in color purity in the lower region of the tube are required.

6. The useful area of the tube surface is too small.

7. Multiple writing of the same word does not make it signficantly different in intensity from singly written words. This indicates that the tube does not have the five level halftone range indicated by the manufacturer.

TABLE I. General Specifications of the Color Storage Tube

Write-gun cathodes (three) indirectly heated	
Voltage	6.3 (ac or dc) volts
Current	1.8 amperes total
Flood-gun cathodes directly heated	
Voltage	1.25 (dc) volts
Current	0.2 ampere per filament Inner circle, 2.8 amperes Outer circle, 4.8 amperes
Phosphor	P25 color, aluminized
Focusing method	Electrostatic
Convergence method	Electrostatic
Deflection method	Magnetic
Over-all length	18 inches
Greatest diameter of bulb	9.25 inches
Useful screen diameter	6 inches

TABLE II. Color Tube 10-11, Operating Data

	V_{vs} = + 6 kv	
	$V_{shadow\ mask}$ = + 400 v	
	$V_{storage\ mask}$ = + 5.0 v	
	$V_{shield\ grid}$ = + 41 v	
	$V_{body\ dag}$ = + 30 v	
	V_{can} = + 34 v	
	$V_{neck\ dag}$ = + 80 v	
	$V_{flood\ gun\ grid}$ = + 5.6 v	
	V_{erase} = + 15 v	
Brightness	0.23 ft. Lamberts	Green gun
	0.19 ft. Lamberts	Blue gun
	0.016 ft Lamberts	Red gun
Resolution	25 lines per inch	Green gun
	20 lines per inch	Blue gun
	20 lines per inch	Red gun
Persistence	2 minutes (usable retention time)	
Cathode	$V_{cathode}$ = -6.0 kv	
	V_{focus} = -5.3 kv	
	$V_{convergence}$ = -3.7 kv	
	Voltages given are with respect to flood cathode potential (ground).	

APPENDIX I

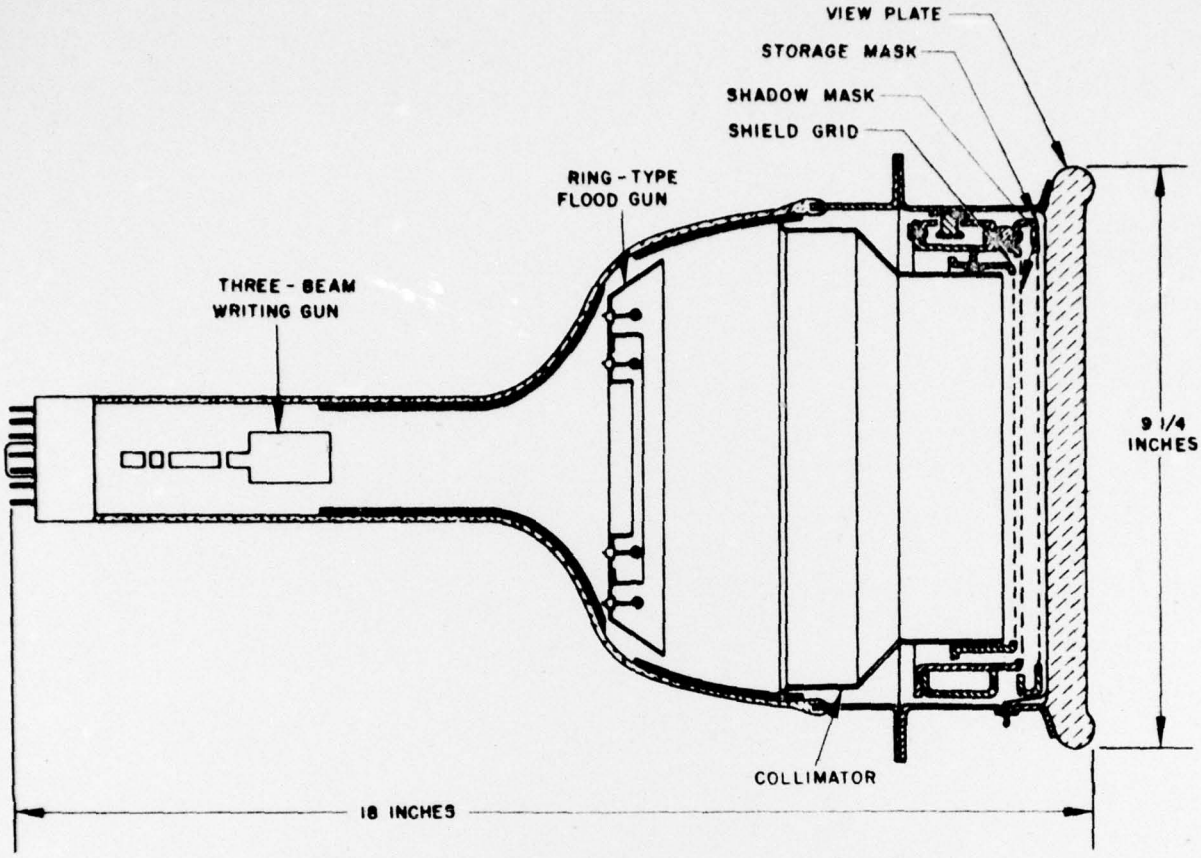


Figure 1. Side View of Ten-Inch Color Storage Tube Indicating the Storage Target, Ring Flood Gun, and Three-Beam Writing Gun

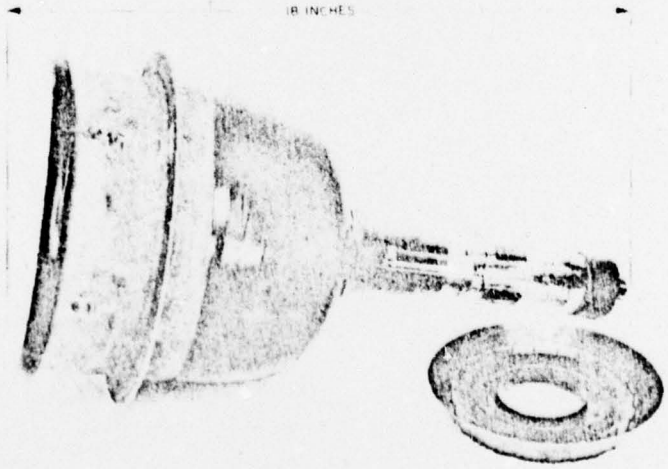
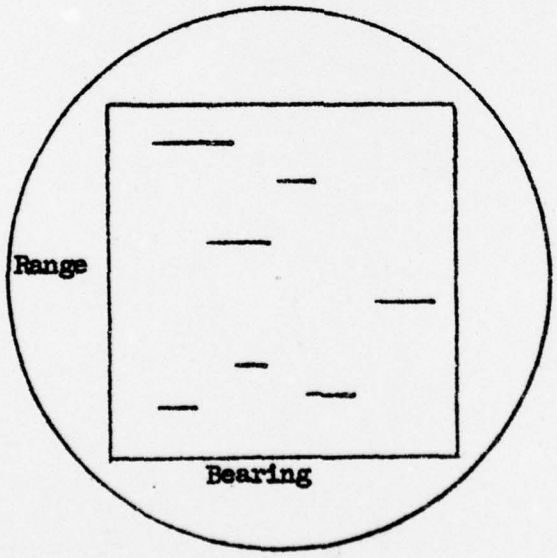


Figure 2. Completed Ten-Inch Color Storage Tube

AMPLITUDE (3 Bits)	DOPPLER (2 Bits)	BEARING (6 Bits)	RANGE (7 Bits)

Figure 3. Data Word



Length = Amplitude

Color = Doppler

Figure 4. Data Display

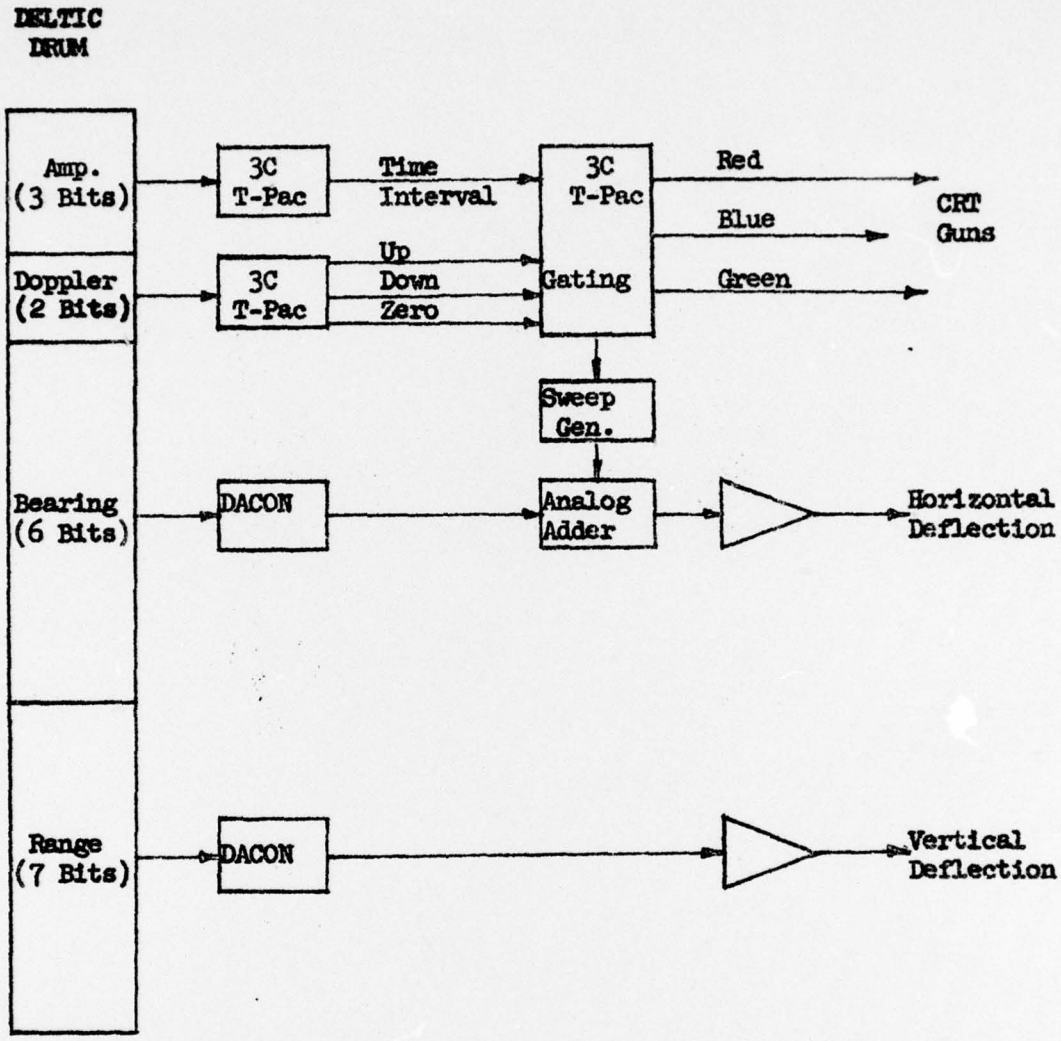
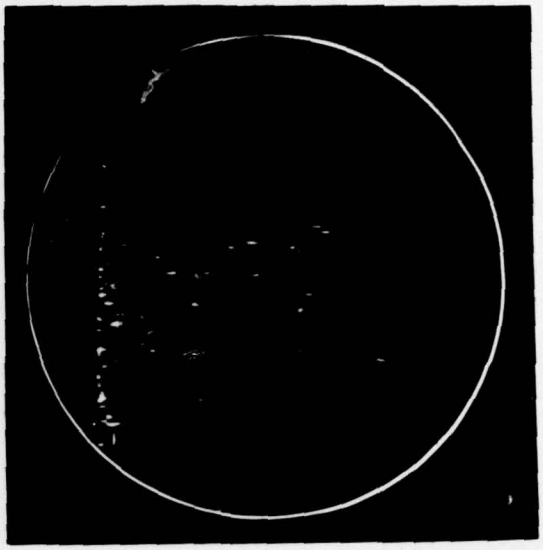


Figure 5. Data Read-Out to Display

A

B-Scan presentation on the 3-Color Tube. Noise background and 2 targets. Because of the low viewing intensity in the lower portion of the screen, the green target in this area is not visible.



B

The same B-Scan presentation as Photograph A viewed on the Tonoscope.

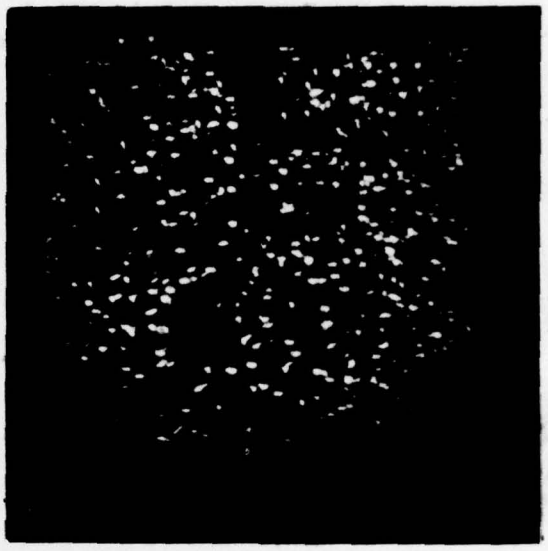
Photograph A description:

Color		Red	Green	Blue
Doppler		Up	Zero	Down
Noise background words	Approx. Number	250	250	250
	Max. Amp.	4	4	4
Target words	Number	1	1	0
	Amplitude	8	8	-

Figure 6. Photographs of stored information.

C

A-Scan presentation on the 3-Color Tube. The same digital information as in Photograph A with the bearing information clamped.



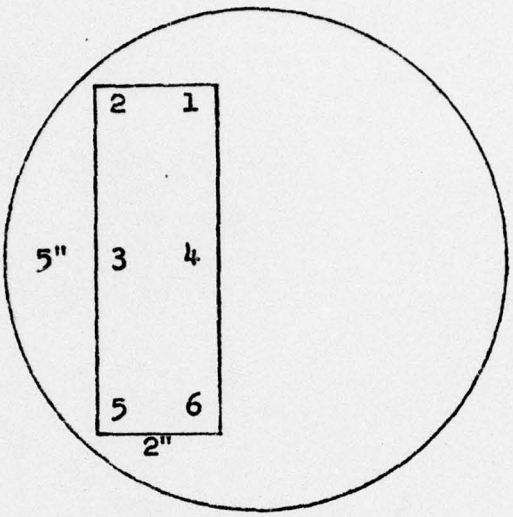
D

Deterioration of the stored information after 2 minutes. Noise background and O targets.

Figure 6. (Continued from preceding page).

TABLE III. Averages of the Experimental Results.

SLIDE DESCRIPTION	DISPLAY DEVICE	TARGETS CHOSEN	TARGETS MISSED	FALSE ALARMS
1. Reverberation background and 2 targets	3-Color Tube	2	0	0
	Tonoscope	2	0	0
2. Reverberation background and 2 targets	3-Color Tube	2	0	0
	Tonoscope	3	1	2
3. Noise background and 0 targets	3-Color Tube	1	0	1
	Tonoscope	1	0	1
4. Noise background and 2 targets	3-Color Tube	2	0	0
	Tonoscope	2	1	1
5. A-Scan and 2 targets	3-Color Tube	2	0	0
	Tonoscope	2	0	0
6. A-Scan and 2 targets	3-Color Tube	2	0	0
	Tonoscope	2	0	0



TUBE SURFACE

Position (Diagram above)	Green (Average Intensity in Ft.	Blue	Red Lamberts)
1	0.23	0.18	0.016
2	0.14	0.12	0.010
3	0.17	0.18	0.010
4	0.23	0.19	0.014
5	0.06	0.02	0.003
6	0.10	0.04	0.005

Figure 7. Average Intensity Results

APPENDIX II

DATA SIMULATION FOR COLOR DISPLAY

A. Data Simulation

To simulate the sonar data, the Remington Rand Deltic was used. The Deltic was not used as a time compressor, but as a drum storage with suitable input and output logic.

To simulate the background (noise or reverberation) data using the Deltic, 17 random "word bit" signals were fed to separate Deltic tracks. (Figure 8). The most significant of the 3 amplitude bits was clamped to "0" during background data storage to reserve the higher amplitude levels for targets. Ten seconds were required to fill the storage drum.

Characteristics of the background data:

Amplitude: Random distribution of levels 1, 2, 3, and 4, on a scale of 8. Higher levels were reserved for targets.

Bearing: Random distribution, 64 combinations, 6 bits.

Doppler: 3 levels, 2 bits, interpreted as up, down, or zero doppler. With no mixing of the two filter output signals, there was a 50% probability that the background word would indicate a doppler other than zero. With equal mixing, all background words would indicate zero doppler. The doppler distribution was continuously variable between these limits.

Range: 7 bits (128 increments), linearly progressing from zero to maximum in 10 seconds.

After storing the background data, target words were read into the Deltic by a preset counter technique. The counter was preset to a number corresponding to the range of the target and the target was then read in and displayed at the time background data of the same range was displayed.

B. Reverberation Limited Background

Number of background words displayed:

Track length = 2000 words

Random amplitudes of 1, 2, 3, and 4 are written on the storage drum, but because of an amplitude threshold, only amplitudes of 3 and 4 are allowed to gate a gun on, therefore 50% of the 2000 words or 1000 words are displayed.

Net words displayed = 1000

90% of background displayed as zero doppler. (Green)
5% of background displayed as up doppler. (Red)
5% of background displayed as down doppler. (Blue)

Doppler Coding:

$\underline{A\bar{B}}$ = up
$\overline{AB}$ = down
$AB + \overline{AB}$ = zero

C. Noise Limited Background

Number of background words displayed:

Track length = 2000 words

AB is not displayed, therefore, 1500 remain.

Only the 50% having amplitudes of 3 or 4 are displayed.

Net words displayed = 750

33% of background displayed as zero doppler. (Green)
33% of background displayed as up doppler. (Red)
33% of background displayed as down doppler. (Blue)

Doppler Coding:

$\underline{A}\overline{B}$ = up
$\overline{A}B$ = down
$\underline{AB}$ = zero
$\overline{AB}$ does not gate any run

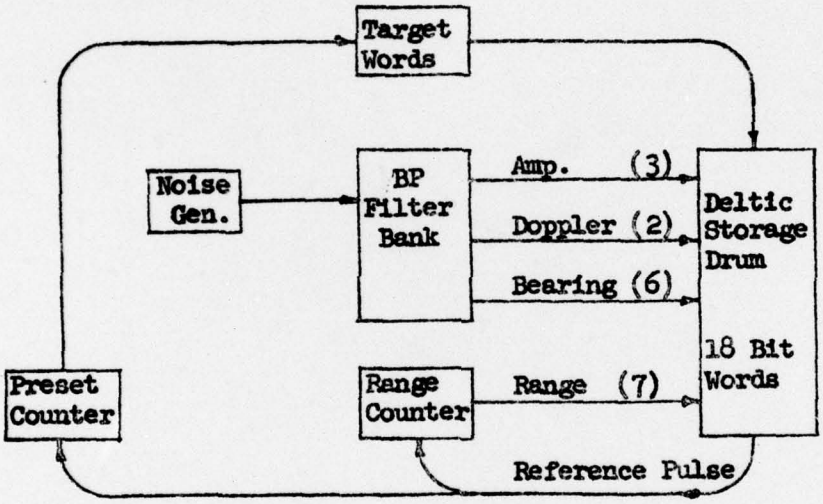


Figure 8. Data Simulation